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Renewable energy technologies in Pakistan: Prospects and challenges

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ABSTRACT

Pakistan is an energy-deficient country. This paper accentuates the importance and challenges of new era technologies. The renewable energy sources like wind energy, solar energy, geothermal energy, ocean energy, biomass energy and fuel cell technology can be used to overcome energy shortage in Pakistan. Renewable energy sources and technologies have the potential to provide solutions to the long-standing energy problems being faced by the developing countries. The expansion of existing energy resources and exploration of new sources is an important exercise to be considered in order to sustain their development initiatives.

Contents

1. Introduction

Energy is a basic concept in all the science and engineering disciplines. A very important principle is that energy is a conserved quantity, i.e. the total amount of energy in the universe is constant. Energy is neither created nor destroyed but just converted from one form to another, e.g. chemical energy into heat, and electrical, or wind energy into electrical energy, etc. [1,2].

Modern society, as we see it today, would have not been possible without energy. It plays a crucial role in the development and well being of a nation. In fact, the progress of a nation could be gauged in terms of how much energy it consumes per person. Energy affects our lives, and livelihoods down to the grass root levels. Energy might best be described in terms of what it can do. We cannot see energy, only its effects; we cannot make it, only use it; and we cannot destroy it, only waste it through inefficient use [2].

- *Renewable energy*: Renewable energy is the energy obtained from regenerative or virtually inexhaustible sources of energy occurring in the natural environment like solar energy, wind

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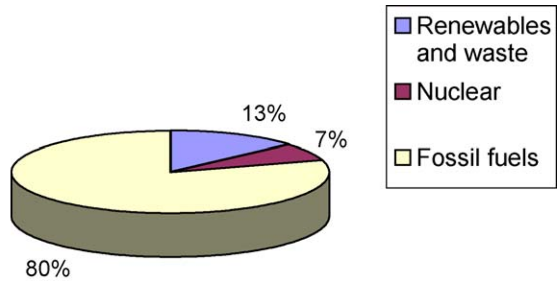


Fig. 1. World total energy-supply in 2000 (IEA).

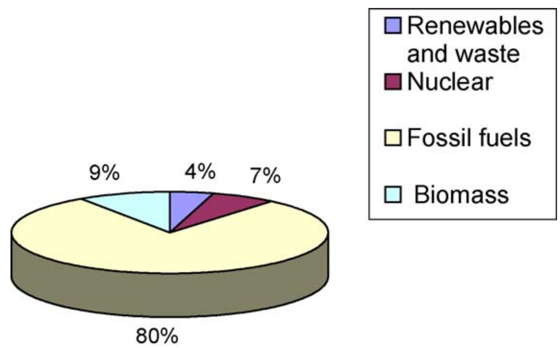


Fig. 2. World energy consumption as reported by WEA 2000.

energy, etc. They are present whether we harness them for practical uses or not. This is also referred as non-conventional sources of energy.

- *Non-renewable energy*: Non-renewable energy is the energy obtained from static stores of energy that remain bound unless released by human interaction. Examples are fossil fuels of coal, oil, and natural gas. This type of energy is initially in an isolated energy potential and external action is required to initiate its supply for practical utilization. This type of energy is also some times called finite energy or conventional sources of energy.

The fossil fuels are diminishing rapidly. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternate sources [2,3].

The area of renewable energy sources is expanding day by day and numerous innovations as well as applications are taking place rapidly. The decentralized renewable energy systems concept has been recognized as an answer to meeting the energy demands both in the household and in the agro-industrial environment. According to International Energy Agency (IEA), in the year 2000, the share of renewable energy supplies that includes hydropower, biomass, wind, solar, geothermal, and marine energy was 13% of the total world consumption while about 80% of the world's energy was met from fossil fuels [4], i.e. from coal, gas, oil, etc., and the remaining 7% is met through nuclear energy. A comparison of global energy supplies and consumption is shown graphically in Figs. 1 and 2, respectively.

We have limited reserves of fossil fuels and these are rapidly depleting. It is believed that after 2050, 50% of the world's energy-supply will come from renewable energy sources.

The magnitude of renewable-energy source (RES) such as solar, wind, biomass, and geothermal is enormous. It is 140 times the worldwide annual energy-consumption. Presently only 0.1% of these are being used. These are enough to meet all our growing energy-needs for long-times to come in the future.

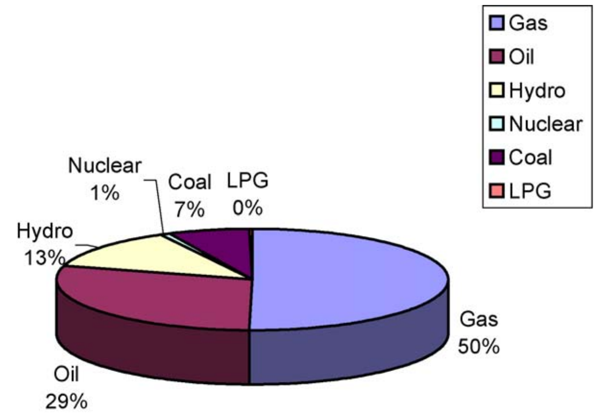


Fig. 3. A graph showing primary energy supplies by source for the year 2003–2004.

2. Choices for Pakistan

If we look at the primary energy supplies of Pakistan for the year 2003–2004, Fig. 3, oil share is 29%, gas accounts for 50%, while the remaining 21% are shared between hydro-, nuclear-, liquefied petroleum gas, and coal energy

A survey of sectoral consumption of different energy sources [1] would reveal that, the primary energy supplies as indicated in Fig. 3 are not enough to meet even the present energy demand of Pakistan. Being energy-deficient country, Pakistan has to spend 3 billion US dollars every year to import oil with annual growth-rate of nearly 1% [5]. This means Pakistan, like other developing countries of the region, is facing a serious challenge of energy deficit. Renewable energy sources can play an important role in meeting this challenge.

The situation becomes alarming if we look at the state of a majority of the people living in remote rural areas having no access to the commercial-energy sources. If energy-services are to be extended to the poorest of the poor living in the far-flung areas to raise their standard of living to a respectable level then we must have to find some alternate method of providing energy at their doorsteps. This goal can be achieved by utilizing renewable-energy sources like wind, micro-hydro, biomass, and biogas.

3. Renewable energy sources of Pakistan: current position and future prospects

The present situation in Pakistan, there is very small activities of renewable energy resources, on the other hand, the objective of Pakistan is to achieve 10% of state electricity generation obtained from renewable resources by 2010 [1,7]. To overcome this deficiency as well to develop suitable environment, marvelous efforts are required.

3.1. Solar energy

Pakistan has great blessings of God especially it is idyllically situated in the sun-drenched belt and can get many benefits of solar energy technologies. The solar energy is lavishly obtainable in the mostly areas of the country. A daily average of global irradiation falling on horizontal surface is about 200–250 watt per m^2 [9]. It is approximately 6840–8280 MJ/m^2 in a year [9]. In our province of Baluchistan Sindh and Punjab are affluent in solar energy. Particularly in Baluchistan, the average daily global irradiation of 19–20 MJ/m^2 a day [9] and daily sunshine duration about of 8–8.5 h and these statistics are amongst the uppermost in the universe [1,9]. The said circumstances are idyllic for all solar

energy applications including solar cell, solar cooker, solar heater, etc. [1,6].

Pakistan has achieved relatively heartening developments in the filed of solar cell technology (PV) technology from last two decades. These are very appropriate at small-scale power generation and remote area applications. According to Federal bureau of the Pakistan statistics, in the start of 1980s about 18 PV stations was built up and installed with in capacity of 440 kW [1,9] for the provision of electricity in the different areas of the country. Due to the lack of technical expertise, the performance of these installed systems is not according to the requirement. But, now with the help of government, there are many organizations have developed the competence-based technologies, and necessary set up to the development of solar cells and modules.

At present, the utilization of solar technology in many areas of electronics, stationary applications, telephone exchanges, emergency telephones at highway, repeater stations, refrigeration for vaccine and medicines in the hospitals, etc. According to statistical date, in the different areas of the Baluchistan, the Department of Public Health has installed about 20 drinking solar water pumps [5,9] in our country, many private and public organizations and research institutes are working hard for the development and improvement of the solar cells and other related technologies.

Many organizations are not only involved in marketing solar cell products and appliances but also fabricating different parts of solar cells and systems. The companies and organization having many solar cell (PV) modules, batteries, regulators, invertors, as well as practical low power gadgets for load shedding such as photovoltaic lamps, battery chargers, garden lights, etc. [5,9].

The perfect utilization of solar energy resources are the two provinces, one is Sindh and second is Baluchistan. According to survey of federal bureau, the 77% are the rural population in the province of Baluchistan [5,9]. The population concentration is slightly very small. There is still about 80% the villages of Baluchistan are yet needed the electricity. The main reason is also that these villages are alienated by large distances. There are no such connecting roads. Therefore, it is very expensive to connect them through any transmitting lines.

In the villages of Baluchistan, the mostly houses are hut/shed type. In addition to food things, electricity is also major need for those peoples. Commonly these houses consist of single room. The electricity for each house is about from 50 to 100 W maximum [1,9]. It is not economical to provide electricity to individuals. Therefore, the solution for these peoples is the only install small-scale power generation systems like solar cells. If diesel generators are used, again there are many problems like transportation of fuel and maintenances and these things make it again expensive. Due to all above said problems, we can say that the solar energy is the only and most excellent solution. One effort also from government is that about 100 homes near the capital of Pakistan, Islamabad are transformed over to solar power to test a new model for the electricity supplying to the people of Pakistan [9].

3.2. Applications of the solar energy

Solar energy has many applications. This technology is very simple, relatively low cost, user friendly and also environmentally free. Such applications like, solar cookers, solar heaters in winters, solar cooling units for the buildings, steam generator, drying for the agricultural products and also food products at particular temperature. One solar water heater also made by COMSATS Institute of Information Technology and Installed at CIIT, Lahore Campus on December, 2007.

4. Biogas

Pakistan, also has a one more great bless of God is an agriculture-based variety. In our villages every family have a sufficient livestock to produce enough animal waste and this can be used for the making of biogas. In our rural areas usually the animal waste is burned for the domestic purpose like cooking food, etc. This waste could be used for producing the biogas at domestic level. So, it is very good opportunity for using biogas to make small domestic biogas plants in the rural areas of the country.

The Pakistan Government (now PCRET) started a Biogas project in 1974. They specially made 4137 biogas plants by 1987 in the rural areas of the country. These plants were designed to grant 3000 and 5000 cubic feet of biogas per day for cooking and lighting purposes [8,9]. This programme was launched in three phases [9].

5. Wind

Wind is also another renewable energy source that could be utilized to overcome the energy crises of the Pakistan. In our country there is no any suitable wind data available. Therefore, the proper depiction related to the availability of wind energy cannot be obtained. There is a marvelous efforts need for the efficient study of the wind data at different altitudes of mountains, predominantly in the most promising sites along the costal line. Average wind speed for some selected sites is not enough for wind power generation to be feasible, although the wind speed can still be utilized to run wind mills to pump water for the areas where it is available at short depths up to 100 ft. [8]. About 1000 km lengthy coastline in the south and some northern mountains of Pakistan have excellent resources for wind energy [2].

In this field still Pakistan have no technical expertise and no suitable wind data for installation of wind mills. But some researchers from Karachi University are trying to collect the wind data and also tried to install some wind turbines for power generation. According to some reports about 30 wind mills have been installed for the purpose of pumping water. Presently one local manufacturer, Merin LTD., is making windmills for water lifting [5,9]. This company sells these mills locally and also to abroad. One wind mill also made by COMSATS Institute of Information Technology for the training purpose under the supervision of UK Engineers and Installed at CIIT, Abbotabad Campus on August 2007. According to email from Executive Director Mr. Khurram Sayeed of Planet Energy (Pvt) Pakistan that they have signed a MOU with China's largest and one of the worlds top ten wind turbine manufacturer's for purchase of turbines for its planned 50 MW with the option of increasing it to 150 MW. The MOU was signed in Urumqui, China.

6. Hydropower

Our Northern areas are very wealthy with hydropower resources. So, our main energy source is still only hydropower. Our 90% electricity depends on it. We have about 12 larger (about 1 MW) hydro-power plants. There are many sites in the high topography, where natural and controllable waterfalls are abundantly exists. The people are isolated in thin cluster and are placed far from physical infrastructure. Such people can get grand advantages from these energy resources.

In the Pakistan, the total capacity for electricity generation is about 19,547 MW. And currently 6600 MW comes from hydropower resources. More than 41,722 MW is identified for hydropower potential in the country [14].

The micro-hydropower (MHP) up to 100 kW is recoverable and is approximately about 300 MW on permanent water falls in northern

areas of Pakistan. Moreover, there is an enormous potential for utilization of water falls in the canal network system especially in Punjab, where the low head and high release of water exists on many canals. In 1910, the Sir Ganga Ram installed a system to generate electricity at the BRB Canal. In This system Kinetic energy converted in to electrical energy. This system is some thing different from hydral power because in hydral power potential energy converts into electrical energy. But there is no such system installed in Pakistan. We can use also this system at our other canals and could provide the electricity at towns' level [9].

The Pakistan Council for Appropriate Technology (PCAT) now called PCRET has installed about 228 "run of river type" [9] plants of 3MW capacity in the North Western region. The recipients themselves do the civil works of power channel, powerhouse, electric poles, and distribution network. But the PCRET provides some equipment and supervision with technical expertise. These small hydropower plants provide electricity for domestic purpose and also to run the small industries like flourmills, cotton ginning, etc. [9].

7. Biomass

The biomass is an efficient and friendly way of disposing of the public waste that is collected in large quantities daily in different cities and towns of the country. But unluckily, there is very little work has been started just now in this decade.

8. Fuel cell technology

Fuel cell is the electrochemical device that converts chemical energy of the fuel (hydrogen) into electricity at high efficiency without combustion. It is similar to a battery, that generally combines hydrogen from any of several sources and oxygen (which can come from air) to produce electricity, heat, and water. Basically, a fuel cell is composed of an anode and cathode, which are separated by a liquid or solid electrolyte. Generally the electrodes are permeable or contain channels that distribute hydrogen or other substances and oxygen. The electrodes are frequently accompanied by catalysts, commonly platinum. In fuel cell, hydrogen atoms enter the cell at the anode where electrons are removed, producing direct current electricity and positively charged ions (protons). Direct current can be converted to alternating current by an inverter. The electrons flow through an external circuit that extends from the anode to cathode. The external circuit can include electric motor, lightening system and other electrical devices. The hydrogen ions travel through the electrolyte to the cathode where they recombine the electron and oxygen to produce water and heat. Fuel cells are viewed as viable power sources for many applications including transport, distributed power generations and portable electronics.

This source of alternate energy has not gained much attention in Pakistan. Presently, there are two small groups; one at Pakistan Atomic Energy commission and the other at COMSATS Institute of Information Technology, Lahore who are trying their luck in this emerging field.

9. Challenges and essential factors for sustainable development of renewable energy sources in Pakistan

To achieve sustainable development in any area of human endeavor in general and energy sector in particular one has to take many things into consideration. This means we have to face many problems and challenges that require planning and concerted efforts to reach the goal. The main hurdles and challenges, which require immediate attention and possible solutions, are:

(1) *Public awareness*: This is the initial step and very crucial in making the sustainable energy program successful. This should be carried out through the media and by public and or professional organization. For this reason, necessary informational input on energy utilization, and environmental impacts of renewable energy resources should be provided to public through public and government channels, specialized agencies and other training facilities.

(2) *Research and development*: Significant research is necessary in renewable energy technology. R&D projects are vital in pre-competitive research in low cost manufacturing processes, testing and evaluation.

- *Human-resources development*: The technology being knowledge-intensive, need highly qualified and trained manpower for research, development, and deployment of these energy technology that cover a wide spectrum of scientific and technical subjects. The universities have to play a very important role to accept this challenge, to introduce new subject to cater the need of emerging technologies. On the other hand, the deployment of technologies demand training of semi-skilled and skilled manpower that can provide the service such as, installation, operation and maintenance; trouble-shooting of the system. Such trained manpower is extremely important for the source and sustainability of the renewable-energy projects. This wills also buildup new business in areas like support-structure and other system-components. It will help to develop niche/consumer-market. So effective training will eventually help to establish local industry and commercial activities for generation of income.
- *Resource assessment*: Reliable data and assessment of energy-sources, technologies, human-resources, research and development, etc., are extremely important and essential at all levels, such as planning, pre-feasibility, project-formulation, assessment, analysis, etc. So there is a strong need of developing necessary resource-assessment tools information databanks.

Infrastructure development: The basic infrastructure for the research, development, and deployment of renewable energy technology either does not exist or is very poor and inefficient in the countries/regions where renewable are most needed. The essential areas are as follows:

(a) *Commercialization*: Renewable energy technologies commercialization will require market preparation as well as market entry support. Market entry support programs should include financial support such as tax incentives for early purchasers, per kilowatt production such as the wind purchase subsidy program, and expansion of the successful renewable energy program for local, state and government and tax exempt entities. Market support also should include non-financial incentives and consistent, uniform treatment of renewable power generation. This includes network of dealers, after sale service, up- and down-stream support-technology. Such an infrastructure is important for sustainability, growth of the market, and to lower the cost of technology.

(b) *Decentralized delivery system*: RET's are decentralized in character, whereas our current experience of handling is only those of centralized energy-system, which have been entirely different requirements. So we have to develop the infrastructure that can handle the decentralized energy-delivery systems more effectively and efficiently.

(c) *Market-development*: Renewable energy technologies are facing a tough time in competing with the conventional energy-source. Public sector can play an important role in

expanding the market by using renewable-energy sources. Public sector can play an important role in expanding the market by using renewable energy technologies on public building, etc. Market expansion will increase production-yield and lower the prices to compete in the free-market. Some governments have taken bold steps to increase the market-volume of renewable energy technology. For example, Germany has installed photovoltaic modules on government buildings [10], whereas Australia extensively used solar energy during Sydney Olympics when stadium was illuminated using PV, and each house of Olympic-village was provide with PV power and solar water-heater [11].

(4) *Educations and outreach*: The Universities seeks a comprehensive, multiyear cooperative education program covering all aspect of renewable energy technology.
- The program should include outreach to decision makers and interested individuals in related professions, communication to code officials and general public education.
- Education programs should target students at all levels.
- Mid-career education should include training for specify build-install-repair professions and trades.

(5) *Government participation*: There are number of incentives for government to promote RES. Some of these are the clean environment, new employment-opportunities, and energy-independence, provision of social services and improving the living conditions in the remote areas, reduction of mass migration from the rural to urban, and saving of foreign exchange on import of energy. These incentives could provide enough driving force for the governments to fund and support the development of renewable-energy market [12,13].

Therefore, the main initiative for the promotion of renewable energy technology has to come from the governments who have to make clear-cut long-term energy-policies that must include a progressive increase of renewable energy technology component. Target is to be fixed and implemented. Consistent policies with positive climates are a must, to encourage the private investors in the field.

(6) *Technology-transfer*: It is extremely important to develop the technologies indigenously for the low price and sustainability of the technology. If some hardware is to be imported, then it must be linked with transfer of know-how for value added development or complete indigenization. Care must be taken not to make the country a dumping ground for foreign technologies.

(7) *Financial incentives*: Currently, RET's largely subsidy-driven. So there is a strong need for initiating bold steps to provide brave incentives to deploy renewable energy technologies and to develop the mechanism to provide easy credit facility, to attract the investment and market-development. A study has shown that in the Sun-belt region, only a tax rebate of 15% can make the PV commercially viable [7] and compatible with the utility.

Government can provide balanced budget resources; provide credits, subsidies, tax rebates, and soft loans; and develop micro financing mechanism for this purpose. Definite, positive development is wherever such facilities have been provided.

(8) *Monitoring and evaluation*: In order to see how successfully, the program has been implemented, it is of great importance to monitor each step and evaluate the data and findings. In this regard, appropriate monitoring and evaluation tools should be used.

10. R&D organizations

The following government and private organizations are involved in R&D of renewable energy sources:

a. Government Organizations.
- Directorate of New and renewable energy, Ministry of Petroleum and Natural resources. This department was responsible for establishment of solar wind turbines village and biogas plants.
- Solar Energy Research Center (PCSIR). The center has been conducting low-level solar thermal applications and has successfully installed a few solar desalination plants.
- Pakistan Council for Renewable Energy Technology involved in R&D activities in silicon solar cells, micro-hydral projects, biogas plants and solar thermal applications.
- A National Commission for Alternative Energy (NCAE) has been established to ensure development of Renewable Energies Technologies in Pakistan.

b. Universities.

A number of Pakistani universities have remained actively busy in R & D work related to renewable energy sources. The list includes:

NED University of Engineering and Technology Karachi, University of Engineering Technology (UET) Lahore, University of Engineering and Technology (UET) Peshawar, Shaheed Zulfiqar Ali Bhutto Institute of Science and Technology (SZABIST) Karachi, University of Karachi, University of Baluchistan, Agriculture University Faisalabad, COMSATS Institute of Information Technology (CIIT), Lahore, BZ University, Multan, and National University of Science and Technology (NUST) Rawalpindi.

c. Private Organizations.
- Techcorp Holding, Inc., Islamabad.
- Grid Solar, Karachi.
- Solargy, Karachi.
- Soltec International, Bahawalpur.
- Merin AgroTools.
- Economia, Islamabad.
- Firex Solar, Islamabad.
- Trillium Pakistan, Rawalpindi.
- Siemens Solar, Lahore.
- Solar Products Incorporated Pakistan, Quetta.
- FINATRA Alten, Karachi.
- Energen, Karachi.
- Wind Baron, Rawalpindi.
- Volta Batteries, Hattar.
- Alternate Energy Group, Advanced Engineering Research Organization, Wah.
- Sun power Systems, Karachi.
- Sahgal Electronics, Rawalpindi.
- Sunpack, Faisalabad.
- Hagler Bailey, Islamabad.

These organizations have developed and promoted Renewable Energy products but most of them remained at modest level and were unable to go in large-scale production.

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